CHAPTER 24

LOW LEVEL RADIOACTIVE WASTE MANAGEMENT IN TAIWAN

C M. Tsai and D. S. Liu

Nuclear Energy Society, Taipei, Taiwan

24.1 BACKGROUND

The commercial operation of Chinshan Nuclear Power Plant (NPP) Unit one marked the beginning of Taiwan's nuclear power program. There are now three NPPs each consisting of two units, in operation. With a generating capacity of 5,144 MWe, nuclear power produces some 30 percent of the electricity supplies in Taiwan. However, the nuclear power component is decreasing as the power demand increases. In order to meet the increased power demand, the Taiwan Power Company (TPC) , a state-run and sole electricity utility in Taiwan, decided to build one more nuclear power plant with two reactors at the Yenliao Site in addition to the other sources. Detailed information about Taiwan's nuclear power program is shown in Table 24.1.

As far as low level radwaste (LLRW) is concerned, TPC is the principal source contributing more than 90 percent of total volume of waste produced in Taiwan. Small producers in the medical and research institutes and universities are responsible for the remaining 10 percent.

24.2 RADWASTE MANAGEMENT POLICY AND ORGANIZATIONAL SCHEME

24.2.1 Policy

On the 16th of September 1988, the Executive Yuan (the Cabinet) promulgated the Radwaste Management Policy (RWMP) that set up the principal guidelines to enable the Taiwan nuclear industry to plan and manage its radwaste. Highlights of the RWMP concerning LLRW are summarized as follows:

- the radwaste producers should strive to minimize the waste generation rate and reduce the volume;
- the responsibility of safely treating, transporting, storing, and disposing of radwaste should rest with the producer. Therefore, the producer is responsible for the necessary expenses; and
- an LLRW disposal site should be located by 1996, and operational by 2002.

24.2.2 Organizational Scheme

The organizations related to radwaste management are shown in Figure 24.1. Both the Atomic Energy Council (AEC) and the Ministry of Economic Affairs (MOEA) are under the Executive Yuan. The Fuel Cycle and Materials Administration (FCMA), a subordinate orga-

Table 24.1. Information on nuclear power plants in Taiwan.

Unit	Reactor Type	Installed Capacity	Commercial Operation	Status
Chinshan 1 (C1)	BWR/4	636	1978	operating
Chinshan 2 (C2	BWR/4	636	1979	operating
Kuosheng 1 (K1)	BWR/6	985	1981	operating
Kuosheng 2 (K2)	BWR/6	985	1982	operating
Maanshan 1 (M1)	PWR	951	1984	operating
Maanshan 2 (M2)	PWR	951	1985	operating
Yenliao	ABWR	1300	2000 (scheduled)	bidding

nization to the AEC, assumes regulatory control over radwaste management matters. The Institute of Nuclear Energy Research (INER) was empowered by AEC to take responsibility for collecting radwaste generated by small producers and treat the waste as necessary. In TPC, the Nuclear Backend Management Department (NMBD) and the Nuclear Operation Department (NOD) take care of radwaste generated by the NPPs. NOD's major responsibility is to supervise treatment and storage of LLRW within the NPPs, whereas NMBD is responsible for radwaste transportation, the operations of both the Lan-yu storage site and the Volume Reduction Center, but more importantly, the final disposal of LLRW in Taiwan.

24.3 TECHNICALASPECTS OF LLRW MANAGEMENT

Before introducing the detailed technical issues of LLRW management in Taiwan, it is better to review the LLRW management diagram (see Fig. 24.2).

24.3.1 Radwaste Generation

LLRW in Taiwan can be divided into two categories: wet waste and dry active waste. Wet wastes, namely: evaporation residues, filter sludges, and spent bead resins, are first solidified in carbon-steel drums and then stored in structurally safe warehouses. Dry active wastes, which are mainly waste paper, clothes, plastics, wood materials, metal, etc., are either segmented or shredded and also stored in warehouses. The cumulative amounts of radwaste generated through August 1994 are listed in Table 24.2. Cement is the most commonly used solidification agent for wet waste. However, bitumen is used in solidifying incinerator ash.

Thanks to waste reduction efforts implemented by industry, the annual radwaste generation rate at the three nuclear power plants has been decreased from more than 12,000 drums prior to 1990 to less than 8,000 drums afterwards. A particularly significant reduction has been achieved for solidified wastes. Together with radwaste generated by small producers, the present annual radwaste generation rate is approximately between 5500 and 6500 drums. Up to now, almost half of the radwaste drums have been shipped to the Lan-Yu National Storage Site for extended storage. However, the remainder of the radwaste is stored in warehouses on site. As the nuclear facilities are nearly running out of storage capacity, a computerized and improved and better equipped on-site warehouse at two of the three NPPs and at INER is either being constructed or is planned. These new facilities are scheduled to commence operation in the near future.

24.3.2 Waste Volume Reduction

Reducing the volume of both combustible and compactable wastes is justified as a good way of mitigating storage pressures given the ever-increasing quantities of

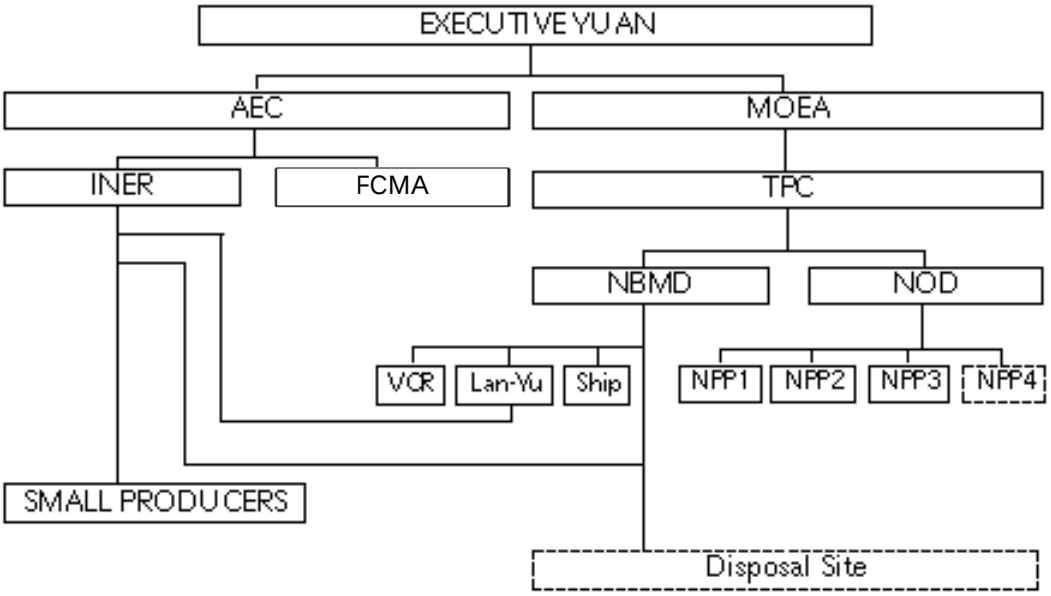


Figure 24.1. Organizations related to radwaste management in Taiwan.

Table 24.2. Total amount of LLRW in Taiwan (unit: 55 gal. drums).

Plant	Solidified Waste	Non-Solidified Waste	Totals
NPP I (C1&C2)	43,684	31,474	75,158
NPP 2 (Kl&K2)	53,090	20,876	73,966
NPP 3 (Ml&M2)	7,004	3,627	10,631
INER	13,774	328	14,102
Total	117,552	56,305	173,857

LLRW. Hence, TPC built a Volume Reduction Center at Kuosheng NPP site. The center comprises a controlled air incinerator and a supercompactor. With a capacity for burning 100 kg/hr of combustible waste and compressing five waste drums per hour of compactable waste, this center is able to eliminate about 3,500 waste drums annually. This has helped to relieve storage problems to a great extent. The important operating parameters of the Volume Reduction Center are shown in Table 24.3. INER has also constructed a controlled-air type of incinerator with a burning rate of 40 kg/hr to treat combustible wastes originating from small producers islandwide.

24.3.3 Lan-Yu Interim Storage

The National Lan-Yu Storage Site provides off-site interim storage for solidified radwaste. This site is located on the small island of Lan-Yu that has an area of about 45 km^2, and indeed, was originally designed as a port of departure for sea dumping that is no longer allowed. Twenty-three semi-underground engineering trenches were constructed on the site, providing a storage capacity of 98,000 drums with three drums being stacked vertically. As of August 1996, the site had received about 97,700 waste drums, and it is anticipated to be full by 1996. However, in a continual search for sufficient storage space and to allow ample time for proceeding with the LLRW disposal program, TPC, the site owner, plans to expand the storage capability by adding six better shielded trenches with a capacity of 59,000 drums. Simultaneously, an optimized waste drum loading pattern will be adopted, making better use of the land. The environmental impact report for this project is under review by the AEC's Environment Evaluation Committee.

24.3.4 LLRW Transportation

Due to the need to continually ship solidified LLRW to the Lan-Yu site before the disposal facility was commissioned, TPC built a modern LLRW transport ship, Teen-Kung No. 1, to replace an old ship in 1991. The new ship is 53 meters long and has a deadweight of 737 metric tons at the designed draft. It can reach a speed of 11.5 knots. Furthermore, it features a double-shell hull,

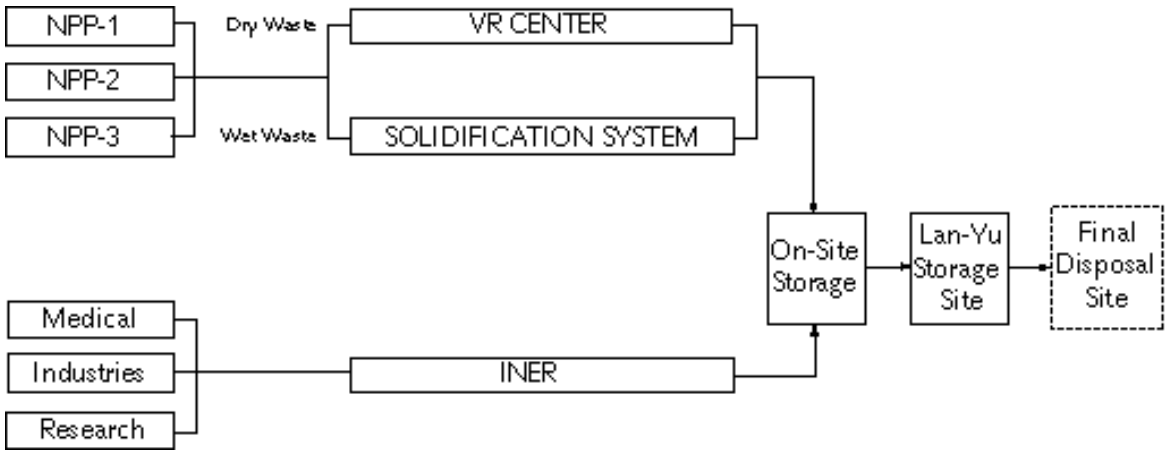


Figure 24.2. Diagram of low level radwaste management in Taiwan.

Table 24.3. Important operating parameters of the Volume Reduction Center.

Parameters	Value
Incinerator:	
Burning rate (kg/hr)	100
Operating temperature (°C)	
1st chamber	700 - 900
2nd chamber	1000 - 1200
Volume reduction ratio	30-100:1
Weight reduction ratio	30-40:1
Supercompactor:	
Compacting force (ton)	1500
Feeding rate (drums/hr)	5
Volume reduction ratio	3 - 5

automatic navigation, satellite-relayed communication, and state-of-the-art radiological protection equipment. It can carry up to 576 waste drums per shipment.

24.4 LLRW FINAL DISPOSAL

Low level wastes presently stored on site or in the Lan-Yu site have to be permanently disposed of in a safe manner. Due to the RWMP direction and in light of the fact that TPC contributes 90 percent of the LLRW generated in Taiwan, TPC has been designated to assume this work.

24.4.1 Regulatory Requirements

According to the "Low Level Radwaste Land Disposal Licensing Regulations" issued by AEC-RWA, the annual dose to any member of the public resulting from release of radioactivity from a disposal site must not exceed 25 millirems (0.25 mSv). When the individual dose is less than 1 millirem (0.01 mSv) and the collective dose less than 100 man-rem (1 man-Sv), the disposal site can then be freed from institutional control. The regulations also point out a set of siting requirements for the final disposal program. They are that the site should:

- be situated in an area with low population density and low development;
- avoid an area in which tectonic activity, geological processes, hydrological and geohydrological conditions could endanger the safety of the disposal facility; and
- be kept away from an area where geological and hydrological data are too complicated to be adequately evaluated.

24.4.2 Geological conditions in Taiwan

Taiwan measures about 36,000 km^2 in area with a spindle shape for the island. There are 81 islets spreading out in the surrounding Pacific ocean, and 64 of them are known as the Penghu Island Group, or the Pescadores, in the Taiwan Strait (Fig. 24.3).

Located at the boundaries between the Eurasian plate and the Philippine sea plate, Taiwan island reaches a maximum elevation of about 4000 m as a result of the compression and shear forces. It is an arcuate island extending its shorter arm eastward to the Ryukyus and its longer arm southward to the Philippines. The backbone of this mountainous island is the Central Range which is mainly Tertiary in age. It is fringed on the west by the Foothill Zone and separated on the east from the Coastal plain with the very shallow Taiwan Strait farther west; east of the Coastal Range is the deep Pacific Ocean. The offshore islets of Taiwan include the Penghu Group in the Strait and Liitao and Lan-yu off the southeast coast. Kinmen and Matsu are two islands close to mainland China covered with Mesozoic granitic gneiss which may be a surface extension to Taiwan. In the less tightly compressed northeastern and southwestern parts of the mountain complex of the Central Range and Foothills of Taiwan, there is the Ilan plain and the Pintung Valley, each in the form of an intramundane trough intruding from the sea into the island.

24.4.3 LLRW Final Disposal Program

The TPC's program plan for LLRWdisposal will be carried out in the following 6 phases:

Phase 1. Selection of Disposal Site and Method
The site selection criteria and process were developed taking into account Taiwan's local conditions and foreign experience. Based on the available geological and socio-environmental situation, a handful of candidate sites will be identified in accordance with siting criteria. Further investigations, including core drilling and laboratory testing on those candidate sites will then follow. Various land disposal methods will be assessed against each candidate site condition to determine those that are suitable. In this manner, the most favorable disposal site

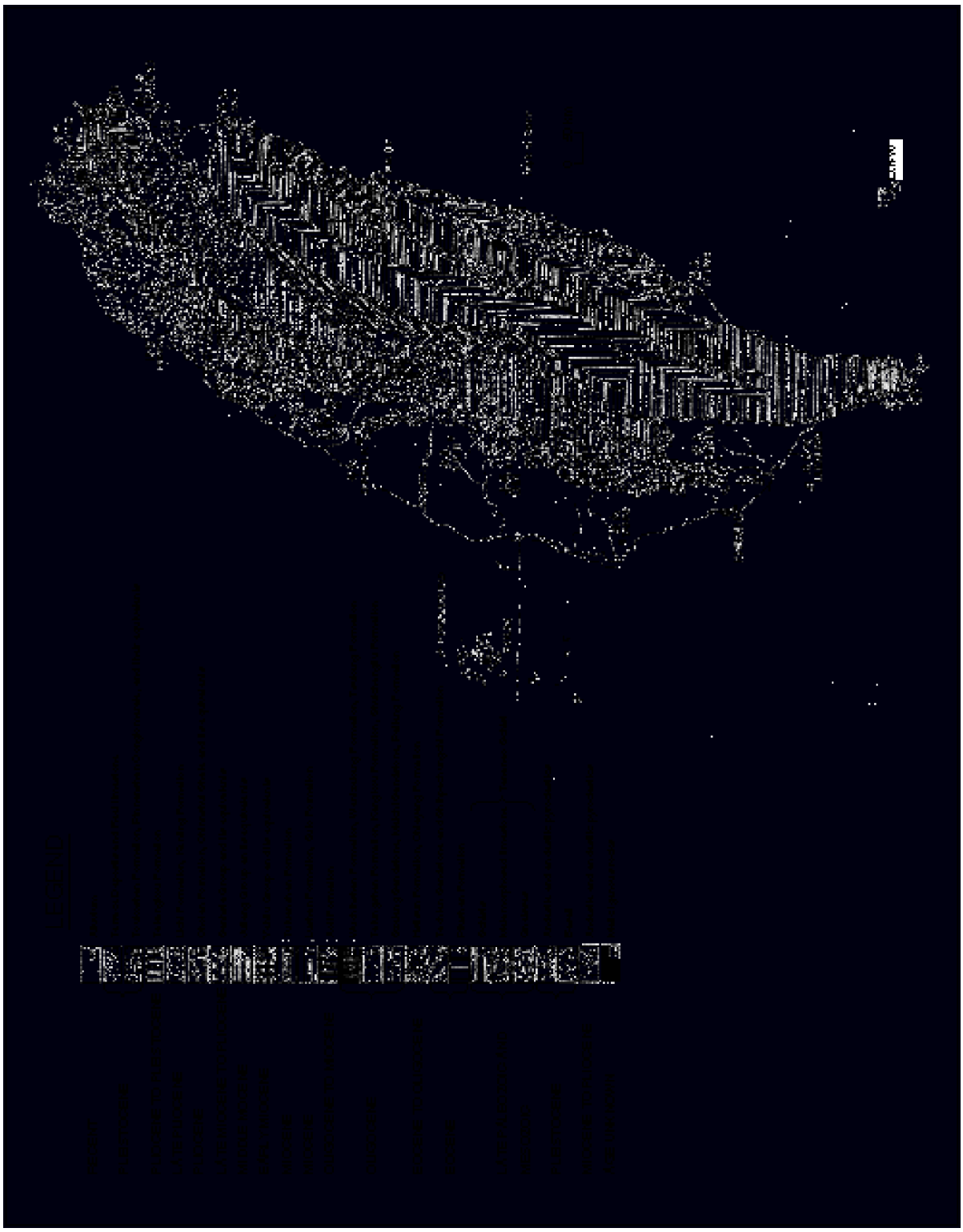


Figure 24.3. General geologic map of Taiwan.

and method can then be selected.

Phase 2. Environmental Survey and Assessment
The environmental data survey and documentation will be conducted in parallel with drilling investigations on the above mentioned candidate sites. Results of the environmental assessment will become part of the attributes used for evaluating and comparing candidate sites.

Phase 3. Site Characterization, Engineering Design and Licensing
It is expected to take at least two years to complete this phase. During the phase, the site characterization, engineering design and the detailed safety analyses will be undertaken to support the presentation of a construction license application.

Phase 4. Site Construction
Depending on the site condition and disposal method, it is expected to take three years to complete the initial phase in the construction of the disposal facility. An operating license application is scheduled to be submitted to the government in 2001 for review.

Phase 5. Operation
The disposal facility is programmed to be commissioned in early 2002 if everything goes as planned.

Phase 6. Post-Operation Monitoring
After the disposal facility ceases operation, it will be backfilled, stabilized, and covered with earth and vegetation. The disposal site and its vicinity will then be monitored until the radioactivity in the disposed waste has decayed substantially and no longer presents a risk to the environment.

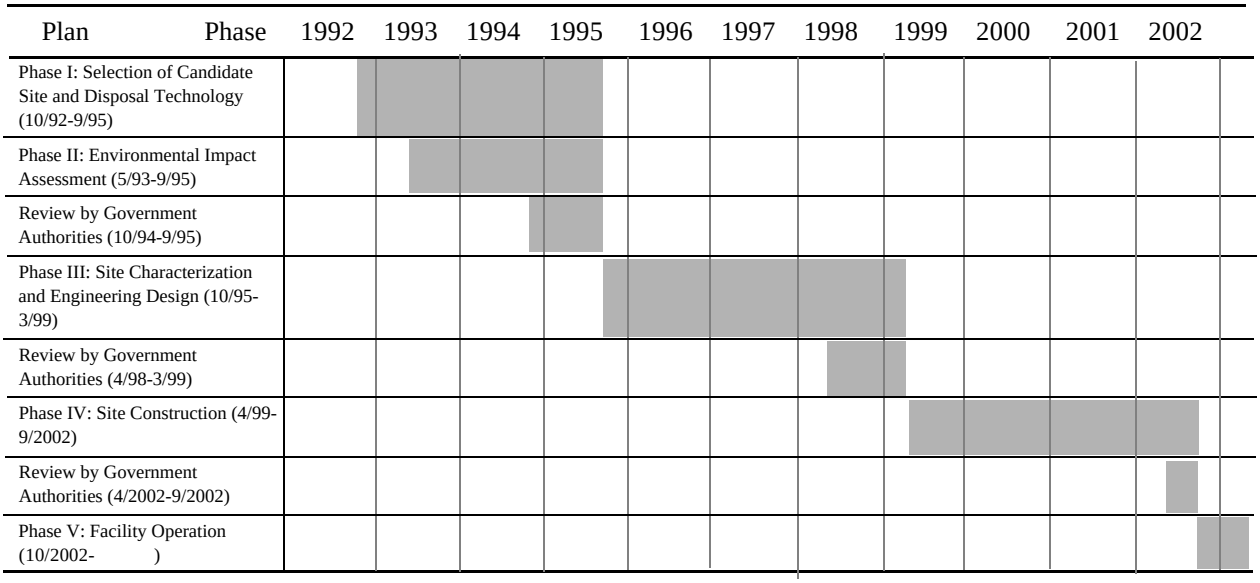
The milestones for each phase of the disposal program are shown in Table 24.4. However, due to nontechnical factors, Phase 1 has been postponed to the end of 1996.

24.5 PUBLIC ACCEPTANCE

The importance of securing public acceptance in proceeding with the LLRW management program has long been recognized by the nuclear industry. The continuing receipt of protests against the storage of LLRW in the Lan-Yu Storage Site from native residents is one of the examples of this kind. Another example could be justified by the strong and violent protests from an opposition party in the parliament to freeze the budget for the construction of the fourth NPP. Currently, the opposition party has about one-third of the seats in the parliament. As elsewhere in the world, nuclear safety and radwaste management in Taiwan have become the two major issues of the anti-nuclear movement.

It is anticipated that, in the future, the establishment of a LLRW final disposal facility could receive many objections from the public since the disposal site will be situated at a given location for a few hundred years. The radwaste people in the nuclear industry are deliberating

Table 24.4. Taipower's overall program plan for LLW final disposal.



on how to get the public involved at an early stage in proceeding with any of the LLRW management programs. To clearly separate the issue of radwaste from that of nuclear power plant development may be strategically important in resolving the radwaste issue. Nevertheless, both to ensure the safety of the final disposal site and to provide a satisfactory financial aid to offset local objections may be the first two essential tasks to be worked on among other things.

24.6 CONCLUSIONS AND RECOMMENDATION

Taiwan is a country of scare natural resources of energy, and, therefore, the use of nuclear energy becomes a necessity. The management of radwaste arising from the use of nuclear power has to be safely planned and implemented. To locate a site, as early as possible, to permanently accommodate LLRWin Taiwan is considered the top priority among other management activities. Since the country is heavily populated and small in area, it welcomes any form of regional cooperation in the disposal of radwaste. Indeed, international cooperation in radwaste disposal is believed to be of benefit to the whole world.

It is hoped that an active program of regional cooperation on the disposal of LLRW can be initiated by a competent organization, such as PBNC (Pacific Basin Nuclear Conference), in light of the potential benefits to this region.

REFERENCES

1. Huang, C. H., Status of radioactive waste management in Taiwan, in Proc. 1993 International Conference on Nuclear Waste Management & Environmental Remediation, Prague, Czechoslovakia, 1993.

2. Huang, C.C., Y.T. Shao, and C.M. Tsai, How a developing country is facing LLW disposal Problem, in the Proc. 1993 International Confer-ence on Nuclear Waste Management and Environ-mental Remediation, Prague, Czechoslo-vakia, 1993.

3. Liu, D.S. Tony, R.T. Lee, and C.M. Tsai, Nuclear waste management in Taiwan - The past three years, in Proc. 1991 Joint International Waste Conference, Seoul, Korea, 1991.

4. Liu, D.S., R.T. Lee, and C.M. Tsai, Efforts of low level waste reduction in Taiwan, in Proc. SPECTRUM'90, Knoxville, Tennessee, 1990.

5. IAEA, Ahandbook for guiding good communication practices at nuclear fuel cycle facilities, Vienna,